Stellar Structure and Evolution Stellar Models

Due February 11

Your task is to compute a stellar model for a chemically homogeneous star using the Matching Point Method. You may choose whatever mass you wish, though it may be easier to get your model to converge if $\mathcal{M} \gtrsim 2\,\mathcal{M}_\odot$. Assume that the composition of the star is $X = 0.75$, $Y = 0.23$, $Z = 0.02$, and use at least $\gtrsim 50$ shells. You may make the following assumptions:

a) Neglect any degeneracy. Except for the very lowest mass stars, degeneracy is not important on the main sequence. The equation of state will therefore contain just two terms: one for an ideal gas (both ions and electrons) and one for radiation pressure.

b) Neglect all energy sources except for the proton-proton chain and the CNO bi-cycle. The energy generated by these reactions (in ergs s^{-1} cm^{-3}) can be approximated via

$$\epsilon_{\rm pp} = \frac{2.4 \times 10^4 \rho X^2}{T_9^{2/3}} e^{-3.380/T_9^{1/3}}$$

$$\epsilon_{\rm cno} = \frac{4.4 \times 10^{25} \rho X Z}{T_9^{2/3}} e^{-15.228/T_9^{1/3}}$$

where T_9 is the gas temperature in units of billions of degrees.

c) For opacity, you may interpolate in the tables given by

`http://cdsweb.u-strasbg.fr/topbase/TheOP.html`

or

`http://opalopacity.llnl.gov`

or use the rough approximations given in the notes. If you choose the latter, you can neglect H^- opacity (for stars more massive than about $1.5\,\mathcal{M}_\odot$), and use

$$\kappa(\text{electron scattering}) = 0.2(1 + X)$$

$$\kappa(\text{free} - \text{free}) \sim 10^{23} \frac{1.4}{\mu_e \mu_I} \rho T^{-7/2}$$

$$\kappa(\text{bound} - \text{free}) \sim 10^{25} Z(1 + X) \rho T^{-7/2}$$

where the opacity is given in terms of cm^2 g^{-1}.

Your output should consist (at minimum) of plots of pressure, temperature, luminosity and radius versus the interior mass of the star. Optionally, you may also make plots of κ, $\epsilon_{\rm pp}$, $\epsilon_{\rm CNO}$, ∇, $\nabla_{\rm rad}$, $\nabla_{\rm ad}$, and/or compare any variable against any other variable.